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A New Strategy for Leveraging Current and Future Simulation Technologies for the U.S. Army

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ABSTRACT

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The fundamental problem with simulations today is the inability of modeling and architecture processes to be dynamic and flexible. Due to budget constraints exacerbated by multiple requirements in an always-changing international crisis-laden world, the U.S. Army needs a new strategy to leverage simulations and modeling for research, analysis, acquisition, experimentation and training. Current issues in modeling and simulation across the Department of Defense, U.S. Army and industry need resolution for future strategic policies and practice. Areas of focus in this paper are modeling and simulation trends, uses, education and information technology. To prepare for the future, a new and ambitious effort must revamp current simulation development processes utilizing "in-house" military expertise for requirements definition, conceptual modeling and project supervision. The military simulation development team will consider Extreme Programming and Advanced Engineering Environment principles to build a simulation program prototype that becomes the basis for awarding "coding only" contracts. This paper outlines an iterative, dynamic and revolutionary strategy for simulation-related technology utilization, both present and future, with application geared towards the effectiveness and efficiency of future simulation programs.

TABLE OF CONTENTS

PREFACE

This is an opportunity for me to acknowledge a few key individuals in this endeavor. General Paul Kern inspired this topic and challenged me to write about a better way to do simulation development. Mr. Walter Hollis, Deputy Undersecretary of the Army (Operations Research) has always given me insightful direction in key trends for simulations. COL Mike McGinnis has always mentored and guided me so much that the gist of this paper was inspired by his tutelage. I thank Dr. Averill Law for his guidance and suggestions in writing about simulations. Lastly, I could not have done any of this without the ardent and able support of my project advisor, Professor Thomas Sweeney, Center for Strategic Leadership.

A NEW STRATEGY FOR LEVERAGING CURRENT AND FUTURE SIMULATION TECHNOLOGIES FOR THE US ARMY

> "We have gone beyond convenience and comfort many times in our history ... all the way back to Valley Forge. The United States of America is capable 24/7/365. If my boss wakes up and says it has to be done this way, in this timeframe, the U.S. armed forces will do it."

—Army Gen. Tommy Franks

Doing what needs to be done when called upon. In the military, commanders and their soldiers, sailors, airmen and Marines are often called upon to perform difficult tasks at late hours. To prepare and meet these challenging times, units must train almost 24/7/365. With multiple missions and requirements, the military seeks to train more efficiently and effectively through simulation-based training— "Simulation has become more important for training as the military increasingly requires young soldiers to be responsible for highly complex, technical, and critical tasks."[1] Leaders and soldiers at all levels now find themselves using complex systems in dynamic situations with an ever-changing and evolving threat.

The Department of Defense (DOD) has many programs that develop and supply Modeling and Simulation (M&S) for military and civilian personnel. Support for DOD M&S programs has yielded returns in military capabilities. While the funding for simulations and automation decreases in the military, demand increases. There are new and evolving global impacts that will affect the future success in sustaining simulations for relevancy in training, analysis, research and acquisition. To meet these challenges, a new or revised strategy is vital—the "status quo" is insufficient.

This paper will propose a new strategy for simulation development that combines current and future automation technologies with creative managerial and engineering approaches. The strategy encompasses all levels and types of warfare including military operations other than war (MOOTW), but this paper focuses on strategic education and operations.

BACKGROUND- MODELING AND SIMULATION TRENDS AND USES

One of the most difficult challenges in simulations is the lack of standardization of data and models for military systems and behaviors. When the Services, Defense Agencies and Department of Defense (DOD) need to integrate data, information and models, there is usually variation in the application of each organization's characteristics and behavior. How one Service views itself is different than how another service considers itself in terms of forces, composition, capabilities and functionalities. Each organization also has a unique purpose for

portraying the other in its own model. In a new era where interagency interactions with military units are crucial, the military faces even greater challenges for standardized and robust modeling.

In order to coordinate efforts in simulation development over the last decade, the Department of Defense Modeling and Simulation Office (DMSO) has fostered new interoperability standards for the services and defense agencies. The standards have sought to use the same simulated environment (terrain, ocean, air and space) representation (SEDRIS[2]) and share hardware/software architectures. This effort intended to enable each organization to model its own forces, composition, capability and functionality, yet be able to interoperate with one another.

In summary, Modeling and Simulation (M&S) for the Department of Defense is a key supporting tool for conducting missions, engineering and research. M&S assists DOD in that it enables leaders and managers to:

- Plan, train, and rehearse missions and operations that are otherwise politically too provocative or dangerous to our people or equipment except under wartime conditions or which would divulge operational capabilities. Due the changing demographics of the International Fellow officers attending the Army War College each year, the Strategic Crisis Exercise must diplomatically adjust the scenario's threat countries.

- Reduce PERSTEMPO and OPTEMPO "wear and tear" on people and equipment for training, as well as, reduce or eliminate the environmental impacts by allowing us to train in cyberspace. M&S is NOT a substitute for the real world but merely a means to enhance the efficiency and effectiveness of real experiences. Sometimes, the process of planning, preparing and evaluating results from simulations is almost as important as the tools themselves. Senior leaders consider the training associated with simulations as a fundamental to prepare units for missions. The Battle Command Training Program at Ft. Leavenworth and the Strategic Crisis Exercise at the Army War College are simulation-based events where the simulation is only a small part of the exercise. The training or education value is in the events that the simulation creates in a future represented world.

- Overcome time, distance and geography by allowing US forces to conduct distributed joint and combined analyses, exercises, training, mission planning and rehearsal, on a connected, worldwide, collaborative basis. Often, it is cost-prohibitive and time-consuming to have units participate in an exercise at a central location. Therefore, distances are virtually eliminated through distributed network connections. For the

strategic and operation levels, video teleconferences, internet meetings and electronic mail augment the simulation-based exercise.

- Improve weapon system design, engineering, test, build and development processes by allowing the assembly of "electronic" prototypes before cutting metal or physically assembling a single hardware component (simulation-based acquisition). Under Dodd's new efforts to streamline and transform acquisition processes, this enabler has the potential to yield a significant return on investment.
- Explore, experiment and assess dynamic and useful transformation concepts for weapon systems, doctrine, organization, logistics, operations, and force structure. Manual and computer-based simulation exercises of the future often stimulate new insights and concepts.

THE DOMAINS

The domains represent the various usage categories for M&S in the military. Since simulations came into favor in the military, there has been a gradual demarcation of boundaries for the predominant usages. In the 1960s and 1970s military and civilian analysts used simulations to study nuclear effects. In the 1980s the training community realized the potential of simulations to train leaders at all levels of command with minimal troop involvement (especially for command post exercises). Finally, in the 1990s, as acquisition management had matured, program managers espoused the utility of simulation-based acquisition. Inherent with acquisition is the simulation-based research and development of concepts, ideas and strategies. Therefore, mainly stemming from the Army's perspective on simulation categories, there are now three domains for simulations—analysis, training and research and development (R&D) (includes acquisition to make this area RDA). Each of these domains will now be discussed in more detail.

Analysis: Analytical models for simulations have always been the basis for fidelity and resolution of combat events, such as, engagements via Lanchester equations. Since the early 20th century, mathematical modeling of sensors, detection theory, terrain, line-of-sight, identification, engagement and attrition have been the foundation of realism for evaluating systems, force effectiveness, and system integration. Today the DOD uses an array of different analytical models and simulations (e.g., TACWAR, Thunder, Brawler, etc.) to conduct force assessments and acquisition reviews. The leadership will replace its current analytical simulation suite of models with one standard and cooperatively-built model, the Joint Warfare System (JWARS). JWARS is a modern analytical model at the operational and joint level for

3

DoD, the services and Combatant Commanders to evaluate war plans, system integration and total force structure analyses. Analytical simulation models also link up with spreadsheet simulations, databases and operational documents. The Joint Operation Planning Execution System has "real world" data and information to input into the analytical models.

Training: As stated previously, there is a drastic need to reduce the amount of time that is wasted in command and control exercises earmarked to train commanders and their staffs. Keeping the troops from mulling around waiting for something to happen is always a training challenge. Thus, the training community realizes the need for improved and realistic simulation-based training. By spending millions of dollars annually and tasking simulation expert trainers (BCTP) and developers to build the "best" simulation, there is a constant struggle between utopian (the user) and realistic (the software developer) forces. The Joint Forces Command employs simulations for training operational level units and leaders. Other Combatant Commands work with JFCOM to use the Joint Training Confederation (JTC) to provide a representation of joint warfare to train component staffs. The JTC uses the Aggregate Level Simulation Protocol to link a collection of standalone warfare simulations—never designed or intended to interoperate with other simulations—into an interoperable confederation. For instance, the Joint Theater Level Simulation (JTLS) allows commanders to train at the operational and strategic levels. Lastly, training does not always require gigantic models running thousands of lines of code. Similar to industrial business strategy gaming, the Army's War College and other service colleges utilize a suite of models and automated tools to lead and motivate role players through futuristic scenarios at the strategic level in campaign exercises.

Research, Development and Acquisition (RDA): The RDA domain combines the analytical models for mathematical theory with the training models for realistic tactics, doctrine and procedures. Both fields need one another to make a case for the employment of futuristic systems in unknown network-centric, information-rich environments. The weapon system of today may be an enabler for the weapon system of tomorrow. One may ponder if the command and control (C2) system will be supported by the combat system in the future. Weapon system program managers develop single-use M&S applications to facilitate weapon systems development, but future trends lean towards multi-use M&S fully integrated with C2 systems. More research and development of joint models will provide the DOD acquisition community a common M&S infrastructure for the modeling of engineering and interoperability issues. For evaluating strategic concepts in transformation wargames, there is a need to employ human-in-the-loop models as a jump-off point for the future RDA domain to use artificial intelligence

4

techniques. One example in this area is the DARPA-funded Center of Gravity program (Disciple) at the Army War College that elicits information to identify the enemy's center of gravity-- a conclusion that the strategic leader would normally depend on a staff to provide. With historical case studies and examples, the Disciple program is one way to reduce the repetitious burdens of staff work in Deliberate and Crisis Action Planning for campaigns.

THE SERVICES

Army: Simulations in the Army have occurred in many shapes and sizes over the years. Even before World War II, the Army conducted a large-scale simulation in Louisiana in which soldiers used brooms to represent weapons while commanders and their staffs moved the units around the fields like pieces in a chess game. Since the 1980s new systems and better force-level training have generated a plethora of simulation models from the engineering level up to and including the strategic level. For training with simulations, the Army's top leader, General Shinseki best articulates the requirement by stating that:

> Better simulations would be critical for training in the future. The Army is fully committed to training simulation as a way of life-- as a way of training large-scale units, echelons of command, divisions and corps, to get our work done. Divisions and corps no longer go to the field as divisions and corps to do FTX (field training exercise)-like or REFORGER (Return of Forces to Germany) exercises. Battalions are still certified in the dirt, but higher echelons of command now certify their mission-essential tasks in simulated dirt called CBS-- Corps Battle Simulation.[3]

From the strategic down to engineering level, the Army's modeling and simulation efforts (mainly out of the Army Modeling and Simulation Office) have oriented on interoperability, standardization and performance. With this in mind, the Army is vigorously building the Future Combat System (FCS), melding simulations and models across all three domains and then assigning a lead system integrator to build a system of systems in accordance with the FCS Key Performance Parameters.

Navy: Naval forces face significant challenges in maintaining readiness while deployed. To alleviate this problem, simulations are increasingly becoming mobile resources, so that deployed forces can maintain and hone their combat skills regardless of location. Also, conducting large-scale naval operations has yielded results to some degree. However, simulation of naval air and sea forces needs to be more robust and integrated. In many cases, naval command and control systems do not interoperate with each other. There are milestones being made in the Navy at all levels. In 2000, the Navy fielded the Joint Tactical Combat Training System (JTCTS) to provide the fleet a fully-mobile, deployable, instrumented training

range system for surface, sub-surface and air operations. JTCTS significantly enhances combat proficiency by providing state-of-the-art "range-less training," with the ability to measure performance and effectiveness on every training event[4]. Operational level and joint modeling needs to have better fidelity and representation. At the strategic level, the Navy continues to run annual wargames at the Naval War College.

Air Force: The Air Force has traditionally used stand-alone, high fidelity weapon system simulators to train its aircrews but the strategic and operational wargames are still being developed. They do have several programs employed for analysis and training. The Air War College games with several air warfare training simulations. However, the air models at the joint and strategic level do not interoperate well with other joint and service models. Since the air operations are key to success in today's battlefield, this area must be seamlessly connected to other simulations. At the tactical level in the Air Force the Distributed Mission Training (DMT) project leverages and dramatically expands the battle space by networking its simulators with real weapon systems. Also, computer simulations replicate the intensity and complexity of real-world, theater-level, air combat. DMT supports the implementation of the Expeditionary Air Force (EAF) concept. However, full employment of the EAF in a theater or regional conflict is incomplete and needs continued development to add air assets as force multipliers.[5]

Marine Corps: The Marine Corps traditionally aligns itself with all of the services as the situation applies to the type of functionality and capability in warfare. In order to capture its multifaceted capabilities with minimal expenses, the Marine Corps synchronizes its simulations with the models the other services develop for land, sea, and air representation. Marine Corps modelers and trainers require good effects in the littoral representation and other battle space areas.   For independent, service-centric activities, the Marine Corps research centers have also devoted resources for analysis in agent-based modeling. Finally, the Marine Corps forces that play in strategic and operational level models are often represented by aggregated models.

Summary: The overall status of simulation development, utility and direction varies today in each Service. This process of having good experience and expertise in modeling and simulation is essential to the Army and DOD. From the trainers' perspective, the inadequacy of current legacy simulation systems does not enable training programs to improve unit and leader proficiency. One opinion associated with training simulations asserts:

> …[with regards to] the effectiveness of the Battle Command Training Program (BCTP) and the use of simulations in support of contingency operations….the Army needs to take a close look at the current family of simulations. Current models do not fully support the requirements of the BCTP and units to conduct rigorous, realistic exercises.[6]

The same statement applies to the analytical and RDA domains. In order to reach a plateau of usefulness that is evenly represented by all services, domains and levels of warfare, a new strategy is essential. A synchronized, concerted effort with cooperation from DOD and the services must repair the effects of parochial development and implementation.

A NEW STRATEGY FOR SIMULATION DEVELOPMENT

A comprehensive and visionary strategy will pave the way for plans and objectives that will fuse current simulation programs with future simulation needs, streamlined processes and technological advances for interchange among all domains and levels of warfare. With proper alignment of manpower, funding, expertise and other resources, improvement in modeling and simulation is very achievable. However, if the military continues to fragment efforts and resources as it does now, a decade from now will see very little change in interoperability, integration and application of simulations. Simultaneously, the technological advances of the next decade will surpass the effectiveness and efficiency of simulation models, creating a void of simulation antiquity—relegating these models with the obsolescent "Pac Man" games of the early 1980s. Therefore, the a new strategy for simulation development does not fully break away the old, but promises to maintain momentum in current developments while preparing to adopt and capitalize on innovative methods and technologies.

THE ENDERS PROJECT

Without a vision and strategy to incorporate and keep pace with technology, the military simulation business will become obsolete. Fleeting is the notion of having a long-term simulation program that is relevant and useful in a dynamic world of new missions, tasks, threats and environmental conditions. For a new approach in future simulation development, the roadmap for a new strategic simulation paradigm will now be presented. The goal is to build an interactive, visually-enhanced, realistic proof-of-principle demonstration of a next-generation simulation system that leaders and their staffs will use to train, analyze and research mission planning, system and force effectiveness designed for any type of contingency with minimal hardware and software constraints. The new program, Project ENDERS (Experimental New Development Extensible Requirements-based Simulation), will revolutionize the way that simulations will be developed in the next decade or two.[7] Incorporating an experimental strategic approach, Project ENDERS would examine the feasibility of a new strategy that dynamically adapts to evolving 21st century requirements and missions.

Project ENDERS leaps ahead to the next-generation of simulation, utilizing current models as a foundation, but building on leading edge components that show great promise and

7

potential for flexible adaptation. The principles and methods for such an endeavor will be outlined in this paper.

SMALL MILITARY SIMULATION DEVELOPMENT TEAM

For this new paradigm, there is a need for a small group of knowledge-area experts and programmers who will maintain close interactions with the customers and managers in the field. This group would most likely consist of military officers with subject-matter expertise at all echelons from tactical to strategic/national levels. Recognizing there are many nations with modeling and simulation strategies and interests, the research team could also research topics with and collaborate with the international community.

The team will also have to hire programmers to code the requirements and functionality. Due to the nature and turbulence of rotational assignments in the military, the team cannot do the programming. However, they would have complete control of a specialized group of programmers operating in accordance with XP principles. XP projects usually involve:

> small groups of programmers, between 2 and 12, though larger projects of 30 have reported success. Your programmers can be ordinary, you don't need programmers with a Ph.D. to use XP, but you cannot use XP on a project with a huge staff. We should note that on projects with dynamic requirements or high risk you may find that a small team of XP programmers will be more effective than a large team anyway.8

The ENDERS Team will have a group of operationally-savvy officers (possibly warrant officers and noncommissioned officers) that know their branch and also possess good technical automation skills. These individuals are subject matter experts (SME) with an operational background, but future aspirations are in simulations, command and control, automation or information operations. The first critical step will be the identification of a Project ENDERS team that has simulation experience and knows how to learn from current and legacy simulation programs. As a fellowship program or internal research effort, the Army should institute a one-year pilot project to prototype the design and working model of a future simulation system. This model would also serve as the basis for requirements analysis by users.

There are some risks to the small team concept. First, the team's size will mean limited expertise and experience. Finding and employing the right individuals with prerequisite experiences and expertise is a challenge that will require senior leader commitment and support to execute. Secondly, the team and charter will have to stay focused and concentrate on the end state with specified objectives.

To mitigate risk and achieve success, the ENDERS Team will follow sound program development methods and effective engineering principles. There are many processes to select

so the team will have to find the one process that fits best for this situation. Two good possibilities, Extreme Programming (XP) and the Advanced Engineering Environment (AEE) will be discussed further in this paper for the team to consider. Less than 10 years old, XP is the latest trend for software development teams and merits good consideration for successful projects. XP inherits ideas from other methodologies, but it focuses teams and efforts with concise and purposeful tasks. The Project ENDERS team will define a terminology and framework that capitalize on both current and future technologies. The degree to which they apply current technology vice the leading edge of future capabilities will be dictated by user requirements and timing for immediate modeling and simulation application.

TERMINOLOGY

To organize the ENDERS project into areas, the team will categorize the components into "seven reasonably independent categories: resolution, domain representation, temporal representation, development approach, representation topic, manifestation and purpose."[9] The first category of resolution distinguishes between black box and glass, or white box models. Glass box models reveal the details of the modeled object's processes where a black box model abstracts those details into undemanding and concealed representations. Functional representation differentiates between using continuous and discrete domains for variables, changes and events in models. The engagement models used by the air functions may differ from those the Army chooses. Temporal representation separates dynamic models that describe time-dependent behavior from static models that do not. Certain activities flow through time, while areas like prepositioned stocks remain static until used.

The development approach stipulates how developers begin the abstraction process. Top-down modeling for manifestation starts at the highest level (national or strategic) and progresses downward. The blueprint for the final product creates the vision and customer buy-in. However, a contractor cannot build a house without setting in a foundation first. In similar fashion, bottom-up modeling is essential as it starts at the lowest abstraction levels and works upward. The purpose of the model outlines the rationale for its utility and function throughout the simulation. Purpose builds the requirements that state the model's use and value. The models need to be small compact code packages that can be interchanged with new or diverse functions and behaviors. The ability to switch a model from combat operations to humanitarian assistance is critical for the future.   These descriptors apply to any model of an object and its behavior. [10] They also form ontology for a universal standard applicable among all of the services, joint operations and even coalitions.

FRAMEWORK

Once the terminology is defined, the team will select a framework that is more flexible and useful than legacy systems currently have. Using a hierarchical approach espoused by Dr. Paul Deitz and Mr. Jack Sheehan, the team can assign every item, object, entity to a certain hierarchical level general framework similar to that proposed by[11]. Within this framework, each item, object or entity will have its own capabilities and features. Based on their level in the hierarchy, each object is expected to perform certain functions in specified circumstances (or instances). The hierarchical approach promises to enhance development across levels of warfare and joint functionality in the services.

Besides just the military levels of warfare, there seems to be a necessity to encapsulate the global and extraterrestrial environments from macro to micro levels. Starting with the world, one may decide that the entities are global and encompassing. A universal model with a robust framework includes peacetime and combat functions, as well as, military and nonmilitary organizations. The quantity of models would increase exponentially, but this facet is long-term work that could be divided among academia, industry and government. With more complexity created by military operations other than war (MOOTW), the new framework will have to be flexible enough to integrate many of these factors.

SELECTING A PROCESS

Every development team employs a specific methodology or process for development, design and operation. Recommending a feasible and promising methodology, the author will persuade the Project ENDERS team to consider the merits of eXtreme Programming (XP). Not intended as a panacea to the hard work and discipline, XP is a new concept in software development that:

> was created in response to problem domains whose requirements change. Your customers may not have a firm idea of what the system should do. You may have a system whose functionality is expected to change every few months. In many software environments dynamically changing requirements is the only constant. This is when XP will succeed while other methodologies do not.[12]

XP appears to be a viable methodology to satisfy military demands for flexibility, innovation, reduced funding and reluctance for specialty programming. The XP process with its detailed steps brings discipline and rigor to such a bold enterprise as Project ENDERS.

Lastly, XP is attractive in that its "real goal has always been to deliver the software that is needed when it is needed." [13] We, in the Army simulation community can relate to this aspect after waiting for future simulations to be delivered in a timely manner. Instead, numerous delays

and schedule slips permeate the simulation development effort. The ENDERS Team should grasp this promise by the XP community and make XP work. In the past, we have often done things this way, but often it conflicted with the process in use—XP is a faster and more efficient way to match military procedures with simulation development processes.

APPLYING PRINCIPLES TO THE PROCESS

Even though there are many engineering and software principles for the team to follow, one set of principles helps to dispel issues and factors that stymie progress in today's demanding and fast-paced software development experience. Advanced Engineering Environment (AEE) principles will guide and direct the ENDERS team. Many of the AEE guidelines reiterate some of the previously-mentioned points, but are worth repeating. The following excerpt describes this ideology by stating that AEE backers should:

> Use commercially available tools as much as possible. In general, the development of application-specific tools should be left to industry. Government agencies should not develop customized tools that duplicate the capabilities of commercially available tools. If available tools are inadequate, government agencies should consider providing incentives for the development of improved, broadly applicable tools by commercial software vendors instead of developing specialized tools themselves. <u>Government agencies should take the following actions to support the development of broadly applicable AEE technologies, systems, and practices to</u>:

> - Improve generic methodologies and automated tools for integrating existing tools and tools that will be developed in the future.
>
> - Develop better models of specific physical processes that more accurately portray what happens in the real world and quantify uncertainties in model outputs.
>
> - Identify gaps in the capabilities of currently available tools and support the development of tools that address those gaps, preferably by providing incentives for commercial software vendors to develop broadly applicable tools.
>
> - Develop test beds that simulate user environments with high fidelity for validating the applicability and utility of new tools and systems.
>
> - Develop methods to predict the future performance of AEE technologies and systems in specific applications and, once implemented, to measure their success in reaching specified goals.
>
> - Explore the utility of engineering design theory as a tool for guiding the development of AEE technologies and systems.

11

- Use contracting requirements to encourage contractors to adopt available AEE technologies and systems, as appropriate.

- Address issues related to the organizational, cultural, psychological, and social aspects of the user environment.

- Provide incentives for the creation of government-industry-academia partnerships to foster the development of AEE technologies and systems.[14]

Even though this list seems exhaustive, it is not inclusive. However, the team should have a checklist with all of these points to include in its program outline and specification development for the strategic plan of building future simulations. Now, with the process and guiding principles, the strategy will seek to leverage modern technology.

LEVERAGING THE CURRENT STATE OF SIMULATION TECHNOLOGY

Before discussing the technological aspects of a new simulation strategy, it is imperative to address education of the organization to enable the effectiveness and efficiency of the strategy. Without buy-in from all of the intended users through an educated process, all of the work will be ineffectual. Education at all levels and services play a vital role in strategizing where simulations are needed and what their requirements should be.

MODELING AND SIMULATION EDUCATION- GUIDING POINTS FOR DECISION-MAKERS AND MANAGERS

Education and training curricula for senior leaders and managers are critical issues for all military leaders. Leaders and managers need to understand simulation capabilities, pitfalls, roles and how to interact in more effective ways. To augment the field of simulation expertise, general and field grade officers in the military should all have knowledge and understanding of how simulations can improve unit training proficiency, analytical studies, experimental research, and acquisition development. Working with users such as the Joint Warfare Center and the Battle Command Training Program (BCTP), simulation-educated officers should oversee simulation development prior to the actual "coding-only" contract is awarded. Currently, the Army is improving its foundation of officers by developing the simulation operations functional area.

Great strides in the last three years are filling the gaps in simulation expertise. Many of these officers have limited technical background, but are being placed in demanding roles as simulation exercise directors and coordinators in Army, Joint and even Coalition training exercises. These roles cover the spectrum of war at combatant commands and Army sites.

Over 80 officers now have the FA57 designator as their primary functional area. With more units demanding simulation-based training linked to their C4I and real-world systems, the demands for FA57 officers certainly exceed the supply. There is the challenge to determine how much the Army needs in terms of operational expertise and technical ability. Officers should be placed in diverse assignments that allow them to improve both sets of skills.

FIDELITY VS PERFORMANCE

For the Army training, acquisition and analysis communities, there is the constant demand for more fidelity that constantly impinges on system speed and performance. Many leaders insist on:

> the need to get to a higher level of fidelity in the execution of operations. The leadership would like to get down to the entity level in execution to provide more realistic feedback to the tactical operations centers….The Army needs to design and field a simulation system that provides more detailed feedback to the commanders and their staffs, and a greater level of fidelity in the execution of missions. CBS [Corps Battle Simulation] works, but the field requires more.[15]

The Army's Warfighter's Simulation (WARSIM) program managers learned a lesson on performance when conducting an initial functionality assessment. The system ran at a speed of 1:5 instead of 1:1 (Simulation Time to Real Time). With all of the level of representation in sensing models, behaviors and aggregation of forces, the WARSIM program ran too slowly. Performance tools were then built to assess the simulation system's performance on the network. The speed and reliability of each simulation system needs to be balanced based on requirements generating the models, infrastructure and architecture for user satisfaction.

As representatives for the community of users, the ENDERS Team must design the simulation model as a system of systems with multiple layers of subsystems that behave differently at various levels of resolution (from engineering level to campaign/theatre level). Aggregation is an unpopular term that carries a lot of baggage and must be designed into the system of systems approach. It is imperative to build methods that allow objects to be persistent individual packages, yet flexible enough to convert to an aggregated system in certain scenarios. This requires the assignment of every item, object and entity to a certain level or echelon. With this level, each item, object or entity will have its own capabilities and features.

For simplicity in a military simulation, the three levels of warfare- strategic, operational and tactical are effective divisions of systems. Each level performs certain functions in specified circumstances or instances. For strategic-level simulations, clock time is often in terms of days and is compressed initially to encapsulate a week or two of events that lead up to hostile

actions. To maximize performance and increase fidelity, the simulation system of systems approach applies to all levels and domains--training, acquisition, analysis and research.

ALGORITHMS AND VALIDATION

Standardization of algorithms and data for validation is critical. The standards that have been accepted over the last 20 years suffice for most uses of simulations. Information and guidance on modeling these are available in current and previous modeling and simulation documentation and other reference material. A subject matter expert will have to encode these standards into algorithms and models. Each of the three domains has analysis tools and models. When working with the other services though, a joint committee will have to decide which components of a model and data apply to the situation and scenario. A concerted effort to categorize and document all of these needs to be done at DoD level for all users. This will reduce the amount of "stove-piped" systems with unique data requirements. These models are sufficiently robust for future models and simulations. Some may lend themselves better for spreadsheet models than actual coding.

For strategic education, there needs to be realism, but the level of validation for that realism does not have to be in computer code. The students at the Senior Service Colleges are interested in seeing results of their actions and decisions. Algorithms could be developed based on student actions from strategic campaign exercises. Tracking electronic mail messages from DoD, combatant commands or other government agencies is just as realistic and meaningful as having a computer program generate the same message. One need only set up a tool for measuring and recording student leader interaction and actions. These data would be the underlying basis for strategic algorithms and heuristics that represent "rough-order" patterns of behavior in strategic crisis action planning and execution. For improved knowledge logic, each War College could employ automated tools that have sophisticated techniques of sensing themes, linkages and relationships from text messages, web sites and electronic mail. Currently, students handle the electronic barrage of information without the same tools that they could use in the real world. In the hunt against terrorists and snipers, organizations like the intelligence community and police departments have used several visual techniques to "quickly understand complex scenarios and volumes of seemingly unrelated data, perform analysis and communicate the results".[16]

EMBEDDED TRAINING

The integration of training scenarios and simulated events into an operational system is a way to include training on a platform so that units can become familiar with a system without

actually using the system for its primary intention. If an M1A2 tank has embedded training software, then the tank crew can simulate direct fire engagements in the tank without firing any live ammunition. Similarly, strategic leaders could use operational joint planning systems for strategic education if those tools are not linked to real world systems and have scenarios reflecting realistic crises.

Embedded training is a critical area for the interoperability of simulations with real-world operational systems for the training on a system to be as realistic as possible. Many future systems will require "inside-the-box" scenario-led tutorial and training. The Objective Force and Future Combat System performance parameters articulate this requirement for efficiency and effectiveness. The Army must follow some of the same concepts as used in the Patriot systems having embedded trainers built in; with technological advances in microchips, the ENDERS Team should consider ubiquitous computing as it predominates the future of computer chips being placed in appliances, cars, and military systems. With the capability to insert microchips in all of these items, software-embedded hardware will accommodate on-board training within the system via simulations.

The US Navy's Battle Force Tactical Trainer (BFTT) program is a good example of inserting training simulations inside real-world command and control systems. One way to enhance the embedded software for training systems is to integrate simulation-based models into the system throughout the system's design process. For embedded design consideration, Dunstan suggests that "an integrated software and hardware development environment that is based around modeling and simulating the whole system and then using this model throughout the development process, the design phases, embedded code development, and verification and validation."[17] The embedded training process applies also to the command and control systems and tools that are available for crisis action planning and deliberate planning at the operational and strategic levels. There is utility in tools that can assist the "unseasoned" joint staff in developing a thorough and relevant campaign plan. The Army is developing mapping, collaboration and database systems for easing use of material and information in crisis action planning. Embedding simulation-based realistic scenarios and events into these tools will help strategic leaders learn how to employ the systems available during deliberate and crisis action planning and execution.

FUTURE TRENDS IN TECHNOLOGY FOR SIMULATIONS

The processes to build simulations are as crucial as the requirements themselves. Without good methods and tools to build flexible, detailed simulation models, the Army

simulation developer cannot maintain pace with the fluid and dynamic battlefields and operations of the 21st century. The two basic components of simulation programs are the behavioral models and computational models. Models are written as source code and converted to executables.[18] The models within the simulation have been developed and written into coded representations of a level of reality. The requirements for "rigorous, realistic exercises" define how rigorously the software modeler will convert real-world objects and their behavior into code. Secondly, a computational model that portrays the environmental effects on weapons munitions (i.e., chemical cloud dissipation in the desert) must be defined "a priori" and with sufficient detail to allow for development and testing of this functionality. Besides the educational aspects of a simulation program, it is also paramount for the military to have the right tools to do the right job and thus fully support the needs of training soldiers and analyzing systems of the future.

As the military adopts this new strategy to develop and design better simulations, each organization and individual team member will have to be attuned to future trends and advances in technologies. Enhancements include improved concepts and software tools touted in the literature as innovative and time-saving methods. Various concepts and tools include the High Level Architecture, commercial-off-the-shelf products, rapid prototyping, standardization languages, intelligent agents, and performance and optimization tools.

HIGH LEVEL ARCHITECTURE (HLA) COMMERCIALIZATION

The ENDERS Team should have a working knowledge of the High Level Architecture (HLA) and DoD plans for commercialization. Full and complete evaluation of the HLA is still incomplete. However, many tools and methods exist that will augment and perhaps replace HLA. Using the internet as an example, web-based technologies and integration may offer a simpler approach for interoperability and integration. The team will also have to reflect on the system of systems paradigm while looking at the standardization where common functions prevail amongst all simulations—i.e. scenario generation, data for models (sensing, engagement, adjudication, etc), map overlay/terrain, weather representation, NBC ops, AAR/output data, and communication systems. The strategic simulation may easily use HLA models since it can filter out extra systems and only subscribe or publish important strategic level activities and units. The matter of complexity of HLA systems could also be an obstacle that joint and combined operations training and analysis may view as cost-prohibitive in terms of training and support. Thus, the ENDERS team should examine alternate emerging trends in this area.

COMMERCIAL-OFF-THE-SHELF PACKAGES

With all of the latest software advances, the ENDERS Team should evaluate, as part of a military procurement effort, whether the modification of commercial packages vice government-developed simulation packages is more economical and effective. One must draw the line in terms of costs, benefits and flexibility. More and more of industry is relying on commercial-off-the-shelf (COTS) packages for its simulations and models. Ministries of defense simulation offices in the Republic of Korea, Singapore and Australia are taking advantage of COTS-based simulation tools and models. These countries do not have large simulation budgets and must economize wherever possible. They try to do much of the work internally and let someone else worry about maintaining and supporting the simulation system after fielding. The US Army's consolidation of contractor-run logistics requirements for simulations consists of a suite of simulations built by a myriad of contractors and government teams. In many cases, the development teams are the only ones knowledgeable enough to make the improvements on the simulation so the government pays exorbitant prices for post-software deployment efforts. For cost efficiency, U.S. military expertise needs to be in the realm of simulation development and design so that the simulations and models for the schools meet user requirements and enhances the educational experience. With the amount of funding for graduate-level schooling, personnel and functional managers have opportunities to utilize the in-house talent of enrolled officers to encourage them to learn more about COTS packages and better ways to build models for the Army.   With support of the graduate professors, military education system leaders could establish a policy that aligns student graduate programs in concert with military knowledge and experience requirements in COTS packages. With many officers in graduate programs as majors and lieutenant colonels, there is room to grow and build the foundation of knowledge to support strategic level simulation development.

SPREADSHEET SIMULATIONS

The concept of spreadsheet simulations involves using spreadsheet programs for course-of-action planning and other "quick looks", mathematical or graphical representation of a real-world situation or object (e.g., a spreadsheet model of business operations or a graphical model of a molecule).[19] Spreadsheet simulations provide a mechanism to "lookup" values to link between levels of hierarchy or echelons. Suited for certain applications, the spreadsheet representation may be limited in scope. The ENDERS Team will assess where and when spreadsheet simulations fit into the simulation component to benefit from this innovative methodology. For strategic level education and application, this area may be the most

appropriate for the ENDERS team to consider. For instance, many of the data and knowledge that a combatant command staff needs are usually in the form of databases and spreadsheets. Strategic and operational level decisions are very broad-based, covering a myriad of categories and functions from air to ground to sea. Therefore, a "quick look" spreadsheet model would provide the rough estimate for the combatant commander to select courses of action or decide on potential branches and sequels.

RAPID DEVELOPMENT

As part of the ENDERS project, the team will rapidly develop simulations from requirements to execution to reuse. Advantageous software features for simulation software include 1) General capabilities, 2) Hardware and software considerations, 3) Animation, 4) Statistical features, 5) Customer support and documentation, and 6) Output reports and plots[20]. These key areas will assist in the building, testing and redesigning of a prototype in rapid, iterative fashion. Various agencies in the U.S. Army and in other countries have sought to build a "battlefield management language" for military command and control systems and for simulations. This effort continues. The ENDERS project team could also work with the tactical, operational and strategic education schoolhouses to test out iterations of the model. Many of the military schools have officers with extensive and relevant experience to provide meaningful and timely input to the model.

EXTENSIBLE MARKUP LANGUAGE

Project ENDERS will need to utilize e*Xtensible Markup Languages (XML*) and metadata tools that are becoming an industrial standard for sharing relevant and valid data and information at all levels. For the military, the XML methodology will enhance data sharing and consistency from the engineering to tactical to strategic level across all services. The Joint Simulation System, COMBAT XXI and Future Combat System programs are currently using XML style sets and conversion tools. A new effort to define a military simulation ontology for XML could revolutionize many of the efforts throughout multinational and multi-agency simulation collaboration efforts. The results at the strategic simulation level would be a smoother process for coalition building and support during a campaign level exercise or operation.

INTELLIGENT AGENTS

Intelligent agents include genetic algorithms, evolution strategies, artificial neural nets, fuzzy logic, rule-based systems and more normally coded into small packages of software

routines. The Defense Modeling and Simulation Office, Defense Advanced Research Programs Agency, the Marine Corps warfighting lab and other countries, such as, New Zealand and Australia continue to exploit intelligent agents in many applications[21]. The U.S. Army War College is also employing intelligent agents to examine the basic fundamentals of determining centers of gravity for campaign warfare.   Many contend that software agents are the key for breaking up large areas of functionality, yet there is still more work to prove this premise. This area of research and application is indispensable for the success of Project ENDERS. Strategic level models empower players with national and strategic intelligence and information sources where intelligent agents could feed data, reports and various messages through a collaborative work environment.

PERFORMANCE AND OPTIMIZATION

The ENDERS team will need to consider available network simulation models and programs to assess the best architecture for a simulation. Predicting the performance of proposed simulation architectures (hardware, software and network) is a new area that several governmental agencies and civilian contractors have assisted the US military in mitigating performance risks. O*ptimization* uses automatic controls that initiate follow-on runs on multiple computers. This is an area that Dr. Averill Law espouses for fast and efficient multiple batch runs in statistical applications with stochastic simulation models[22]. The team should review simulations like the Joint Warfare System (JWARS) that is seeking ways to run an auto mode (automatic mode) configuration based on scenario sizes and activity in order to optimize and repeat runs. For long-term representation of timelines that allow for diplomatic and economic instruments of power to be employed, optimization of time could occur through an auto mode function.

CONCLUSION

The myriad suite of simulations permeates all facets of professional military education. According to a recent article that announces a restructuring of junior officer to field grade education, "Simulations will be used extensively to drive the learning and multiple opportunities will be provided for officers to practice their warfighting competencies and skills."[23] When the field grade leaders become senior leaders, they will expect simulations to be a part of their strategic education. If the military waits 10-15 years to change its simulation development strategy for all levels of warfare, senior leaders will be sorely disappointed.

Past experiences in exercises, operations and academic institutions shape the demand for a new strategy to shorten timelines, reduce costs and improve functionality and

19

performance. The Army must leverage modeling and simulation for its warfighting missions. The constant demand by leaders and warfighters for more functionality and performance is essential to keep leaders interested in employing simulations for training, analysis, mission rehearsal, acquisition and experimentation. Innovation is the key to success. As defined by Dr. Frances Hesselbein, innovation is the "change that creates a new dimension of performance." This strategic plan energizes a reliable process to perform in accordance with the expectations of future senior leaders in 10-15 years.

This paper articulates a new strategy for simulation development that embraces both current and future automation technologies. With accurate design and disciplined engineering, the development and implementation of a simulation program for all levels of warfare and even military operations other than war will succeed. Strategic levels of warfare are the most difficult to model, but their utility sets the stage for the remaining levels. Also, the strategy of simulation development, factored with newly-available implementations in software tools and methods, will cultivate a process by which funding, planning and execution of the next generation simulation represents the most cost-effective and operationally-effective simulation.

Now is the time for us to start planning a simulation strategy to take current technologies and meld in new tools and opportunities. The Army should not wait, but immediately develop and implement a strategy to prove concepts for building the next generation of simulations.[24] We should heed the words of Thomas Edison that he told his researchers there is a better way to do it and exhorted them to find it—*and once we do find the better way (often through trial and error), let's do it!*

WORD COUNT = 8004.

ENDNOTES

[1] Scott Nance, "Conference Demonstrates Growing Demand For Modeling and Simulation," *New Technology Week* 16, No. 49 (2002): [journal on-line]; available from <http://web.lexis-nexis.com/universe>; Internet; accessed 11 December 2002.

[2] Synthetic Environment Data Representation Interchange Standard; more information is available from <http://www.sedris.org> or <http://www. dmso.mil>.

[3] Neil Baumgardner, "Shinseki: Army Needs Better Simulations," *Defense Daily*, September 5, 2002, 5.

[4] "Joint Tactical Combat Training System (JTCTS)"; available from <http://www.raytheon.com/products/jtcts/>; Internet; accessed 19 Mar 2003.

[5] "USAF Distributed Mission Training", available from <http://www.afams.af.mil/programs/projects/afdmt.htm>; Internet; accessed 18 Mar 2003.

[6] James Cobb and Bob Fielding, "The Battle Command Training Program and Army Simulations"; available from <http://call.army.mil/products/newsltrs/01-14/01-14ch3.htm>; Internet; accessed 10 Sep 2002.

[7] The Army Material Command HQs, Air Force Studies and Analysis Agency, Army G-3, USMC Development Center and USCINCPAC (JO8) are among initial supporters for this effort. FA57 officers in the field and en route to graduate studies have also expressed a desire to participate in Project ENDERS (Dr. J. Henningsen's reference of future combat described in Orson Scott Card's *Ender's Game* inspired the author in this effort).

[8] Don Wells, "Extreme Programming: A Gentle Introduction"; available from <http://www.extremeprogramming.org/when.html>; Internet; accessed Feb. 9, 2003. For the practical aspects of XP, see Kent Beck's XP series of 7 books that covers XP definitions, planning, practice and development in more detail.

[9] Scott Harmon, "Just Words-Just Models," 20 June 2001; available from <http://www.sisostds.org/webletter/siso/iss_75/art_361.htm>; Internet; accessed 20 Aug 2002.

[10] Wells.

[11] Paul Deitz, Bruce Harris, Jack Sheehan and A.B.H. Wong, "A General Framework and Methodology for Analyzing Weapon Systems Effectiveness", March 2001.

[12] Wells.

[13] Ibid.

[14] National Research Council, Advanced *Engineering Environments, Achieving the Vision, Phase 1*, Committee on Advanced Engineering Environments, Aeronautics and Space Engineering Board Commission on Engineering and Technical Systems, (Washington, D.C.: National Academy Press); available from <http://books.nap.edu/html/adv_eng_env/ch5.html>; Internet; accessed 21 Sep 2002.

[15] Cobb and Fielding.

[16] A company named *i2* reported that their "data visualization and link analysis software, received a letter of commendation from the Maryland State Police for its support during the recent Washington Metropolitan Area Sniper Investigation. Following a request from the Maryland State Police, *i2* 'delivered and configured software that played a critical role in the organization and analysis of intelligence information gathered during the investigation.' This commendation is similar to a letter *i2* received from the Director of the FBI for its assistance following the September 11, 2001 attacks in New York, Pennsylvania and Virginia."; "i2 Receives Commendation from Maryland State Police for Assistance During Washington Metropolitan Area Sniper Investigation"; available from <http://www.i2inc.com/Company/Press/0103.asp>; Internet; accessed 4 Mar 2003.

[17] Kent Dunstan, "Model Design—A Better Way to Develop Embedded Control Systems", 2002 SIMTECH Proceedings, (Melbourne, Australia, 2002), 1.

[18] Harmon.

[19] Harmon.

[20] Averill Law and David Kelton, *Simulation Modeling and Analysis*, (Boston: McGraw-Hill, 2000), 208.

[21] Clint Heinze. "Developing Agents for Military Simulation: From Knowledge Acquisition to Deployment", Workshop on the Military Applications of Intelligent Agents. SimTecT, Melbourne, May 13, 2002.

[22] Interview with Averill Law, 6 April 2002.

[23] Marcia Triggs, "Army To Transform Officer Education System", Army News Service, January 16, 2003 (released Feb. 4, 2003).

[24] With a focus on a new strategy for developing military simulations, the author will propose this venture to senior leadership (Army, other services and joint) in June 2003. Upon approval, an ENDERS team would begin work on a small scale and then expand it in 2004 once the strategy demonstrates success.

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